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In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

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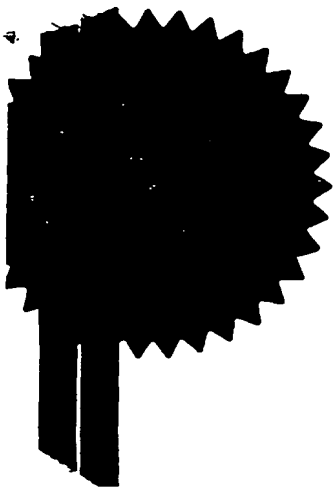

Signed A W Brewer

Dated 6 MAR 2000

Patents Form 1/77

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03FEB99 E422256-5 D00239
P01/7700 0.00 - 9902253.5

Request for grant of a patent

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The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference — DM/EN/P08788GB

2. Patent application number *(The Patent Office will fill in this part)* — **9902253.5**

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Rotech Holdings Limited,
Whitemyres Avenue,
Mastrick Industrial Estate,
ABERDEEN, AB2 6HQ,
Scotland, United Kingdom.

Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation — United Kingdom

4. Title of the invention — IMPROVEMENTS IN AND RELATING TO BEARINGS

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Cruikshank & Fairweather,

19 Royal Exchange Square,
GLASGOW, G1 3AE,
Scotland, United Kingdom.

Patents ADP number *(if you know it)* — 547002

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body
See note (d))

YES

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	7
Claim(s)	-
Abstract	-
Drawing(s)	2 +2

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature CRUIKSHANK & FAIRWEATHER Date 02/02/99

12. Name and daytime telephone number of person to contact in the United Kingdom

Dr. David Moreland
0141 221 5767

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.

b) Write your answers in capital letters using black ink or you may type them.

c) If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.

d) If you have answered 'Yes' Patents Form 7/77 will need to be filed.

e) Once you have filled in the form you must remember to sign and date it.

f) For details of the fee and ways to pay please contact the Patent Office.

IMPROVEMENTS IN AND RELATING TO BEARINGS

This invention relates to an improved bearing. Particularly the invention relates to an improved bearing assembly, e.g. a thrust bearing assembly, which may be used in down-hole applications, e.g. down-hole drilling applications.

Thrust bearing assemblies for use in down-hole applications have the conflicting requirements of a thick shaft assembly and high axial load bearing capacity in a small cross-section. To achieve this a number of thrust bearings may be mounted in line to provide sufficient load and shock capacity. In conventional bearing assemblies this introduces a problem as the load may not be shared equally between the series of bearings which may result in excessive wear or failure of one or more of the bearings. This problem can be mitigated by use of assemblies of springs and spacers. However, these tend to be complex in nature. An additional problem in down-hole apparatus is that space tends to be limited.

It is an object of at least one aspect of the present invention to obviate or mitigate the aforementioned problems in the prior art.

It is a further object of at least one aspect of the present invention to seek to provide a flexible, load sharing, anti-friction bearing assembly/unit.

According to a first aspect of the present invention there is provided a bearing assembly having at least two bearing elements spaced by a first body, the first body

having means for flexing.

Thus when a load is applied to the bearing assembly the first body may be caused to flex.

Advantageously the flexing means may comprise at least one groove or notch formed on the first body.

Preferably the first body is substantially annular in shape, the at least one groove preferably being formed on an outer surface of the first body.

Advantageously the groove is substantially U-shaped.

The first body may be rigidly mounted to a body to which load is applied, in use.

Preferably a first annular surface of the first body is provided with a first annular raceway.

Preferably also, a second annular surface of the first body is provided with a second annular raceway.

Advantageously the first and second bearing elements each comprise a plurality of balls, the first and second bearing elements preferably being received for movement within the first and second annular raceways of the first body.

According to a second aspect of the present invention there is provided a bearing unit comprising at least one and preferably a plurality of bearing assemblies according to the first aspect.

Advantageously each adjacent bearing assembly are spaced by a second body.

Preferably the second body is substantially annular in shape.

The second body may be rigidly mounted to a further

body to which load is not (directly) applied in use.

Preferably a first annular surface of the second body is provided with a first annular raceway.

Preferably also, a second annular surface of the second body is provided with a second annular raceway.

Advantageously, respective first and second bearing elements may be received for movement within the first and second annular raceways of the second body.

Advantageously, adjacent first bodies are spaced by a respective first spacer element.

Advantageously also, adjacent second bodies are spaced by a respective second spacer element.

According to a third aspect of the present invention there is provided a tool or apparatus including a bearing assembly according to the first aspect of the present invention or a bearing unit according to the second aspect of the present invention.

The tool may be a down-hole tool, e.g. for use in a borehole of an oil/gas well.

The tool may comprise part of a borehole drilling apparatus, which may include a down-hole motor such as a Moineau motor of a motor as disclosed in WO 95/19488, the content of which is incorporated herein by reference.

The first body may be rigidly mounted to a shaft to which load is applied, in use.

The shaft may be contained substantially concentrically within the bearing assembly/unit.

The second body may be rigidly mounted to a housing.

The housing may substantially concentrically surround

the bearing assembly/unit.

Advantageously, adjacent first bodies are longitudinally spaced by a first spacer element, which may also be mounted on the shaft.

Advantageously also, adjacent second bodies are longitudinally spaced by a second spacer element, which may also be mounted on the housing.

An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, which are:

Fig. 1 a portion of a down-hole tool including a bearing assembly according to an embodiment of the present invention;

Fig. 2 a perspective view of a portion of the bearing assembly of Fig. 1.

Referring initially to Fig. 1 there is illustrated a portion of the down-hole tool, generally designated 5, according to an embodiment of the present invention. The tool 5 may take the form of a borehole drilling apparatus. The tool 5 includes a bearing unit (pack) 10 comprising a series of adjacent bearing assemblies 15 - in this embodiment three assemblies 15 are provided.

Each bearing assembly 15 has two anti-friction bearing elements 400 spaced by a first body 500, the first body 500 having means for flexing. Thus, when a load is applied to the bearing assembly 15, the first body 500 is caused to flex. In this embodiment the flexing means comprise at least one groove 510 formed on the first body 500.

The first body 500 is substantially annular in shape,

the at least one groove 510 being formed on an outer surface of the first spacer body 500. As can be seen from Figs. 1 and 2 the groove 510 is substantially U-shaped.

The first body 500 is rigidly mounted to a shaft 600 to which load is applied, in use, the shaft 600 being substantially concentrically contained within the bearing unit 10. The shaft 600 may be hollow and may have a socket 610 for connection, e.g. to a drill bit or the like (not shown).

A first annular surface 610 of the first body 500 is provided with a first raceway 620. Further a second annular surface 630 of the first body 500 is provided with a second annular raceway 640. The first and second bearing elements 400 each comprise a plurality of balls, the first and second bearing elements 400 being received for movement within the first and second annular raceways 620, 640 of the first body 500.

The bearing unit 10 comprises a plurality of bearing assemblies 15. Each adjacent bearing assembly 15 are spaced by a second body 200. Each second body 200 is substantially annular in shape. The second bodies 200 are rigidly mounted to an outer housing 100 to which load is not (directly) applied, in use.

A first annular surface 650 of each second body 200 is provided with a first annular raceway 660. A second annular surface 670 of each second bodies 200 provided between adjacent assemblies 15 is provided with a second annular raceway 680. Second bodies 200 provided at ends of the unit 10 are only provided with one raceway 660.

In this way respective first and second receiving elements 400 are received for movement within the first and second annular raceways 660, 670 of the second spacer body 200.

Referring to Fig. 1 the second bodies 200 are rigidly mounted to a housing 100. The housing 100 substantially concentrically surrounds the bearing unit 10.

A first raceway 620 of the first spacer body 500 faces a second raceway 680 of a second body 200. Similarly a second raceway 640 of the first body 500 faces a first raceway 650 of a second body 200.

As can be seen from Fig. 1 the first bodies 500 are longitudinally spaced along the shaft 600 and separated by first spacer elements 700 which may be rigidly mounted to the shaft 600. Further as can be seen from Fig. 1 the second bodies 200 are longitudinally spaced along the housing 100 and separated by second spacer elements 300 which may be rigidly mounted to the housing 100.

It is noted that the shaft 600 is free to rotate relative to the housing 100. Thus the first bodies 500 may rotate relative to the second bodies 200.

The components of the tool 5 may, in this embodiment be made from the following materials:

housing 100	-	steel
second bodies 200	-	hardened steel
second spacer elements 300	-	steel
bearing elements 400	-	hardened steel and/or ceramic
first spacer bodies 500	-	hardened steel

shaft 600	-	steel
first spacer elements 700	-	steel

In use, the flexibility of each bearing assembly 15 provides load sharing throughout the bearing unit 10. This flexibility is imparted by the grooves 510. As a (thrust) load F is applied to the shaft 600 a first body 500 deflects or flexes under the load F seeking to ensure that the next first bodies 500 are suitably positioned such that some of the load is then transferred through the adjacent inner spacer 700 to the next first body 500 and so on. This seeks to ensure that the load F is spread evenly between the bearing assemblies 15 in the unit 10, and is not supported by a single bearing assembly 15. Thus the load F is distributed in a way which is not possible using known rigid bearing assemblies. As each body 200, 500 is double sided the load F may be either tensile or compressive. In either case the load F will be shared over each of the bearing assemblies 15 of the unit 10.

It will be appreciated that the embodiment of the present invention hereinbefore described is given by way of example only, and is not meant to limit the scope of the invention in any way. It will, for example, be understood that the number of bearing assemblies forming a bearing unit may be selected to provide a desired load capacity.

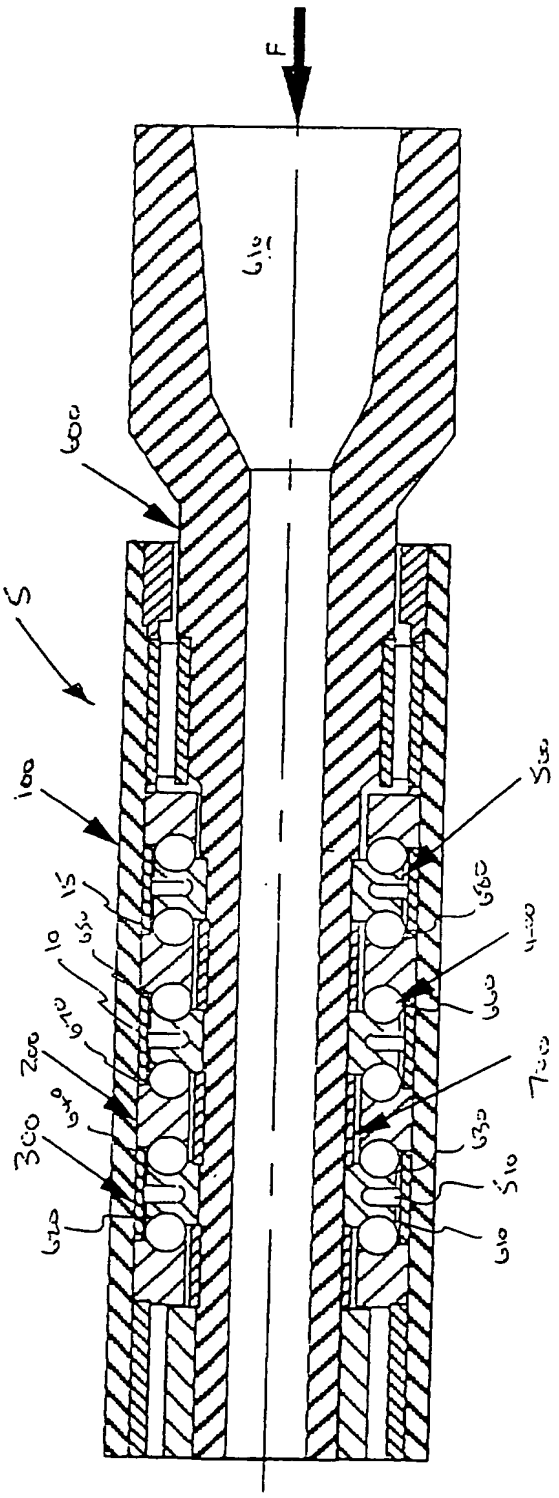
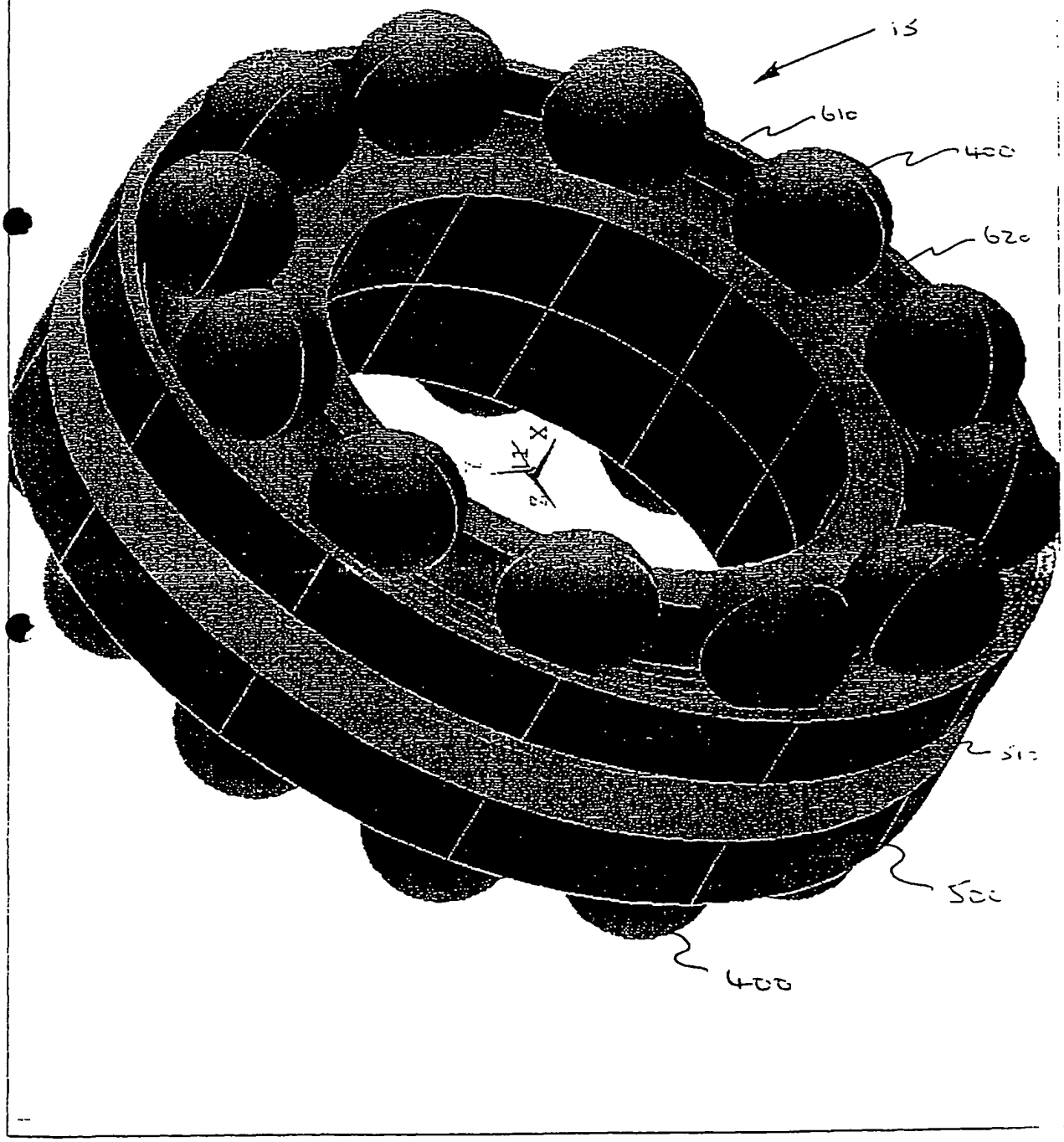


Figure 1

FIG. 2



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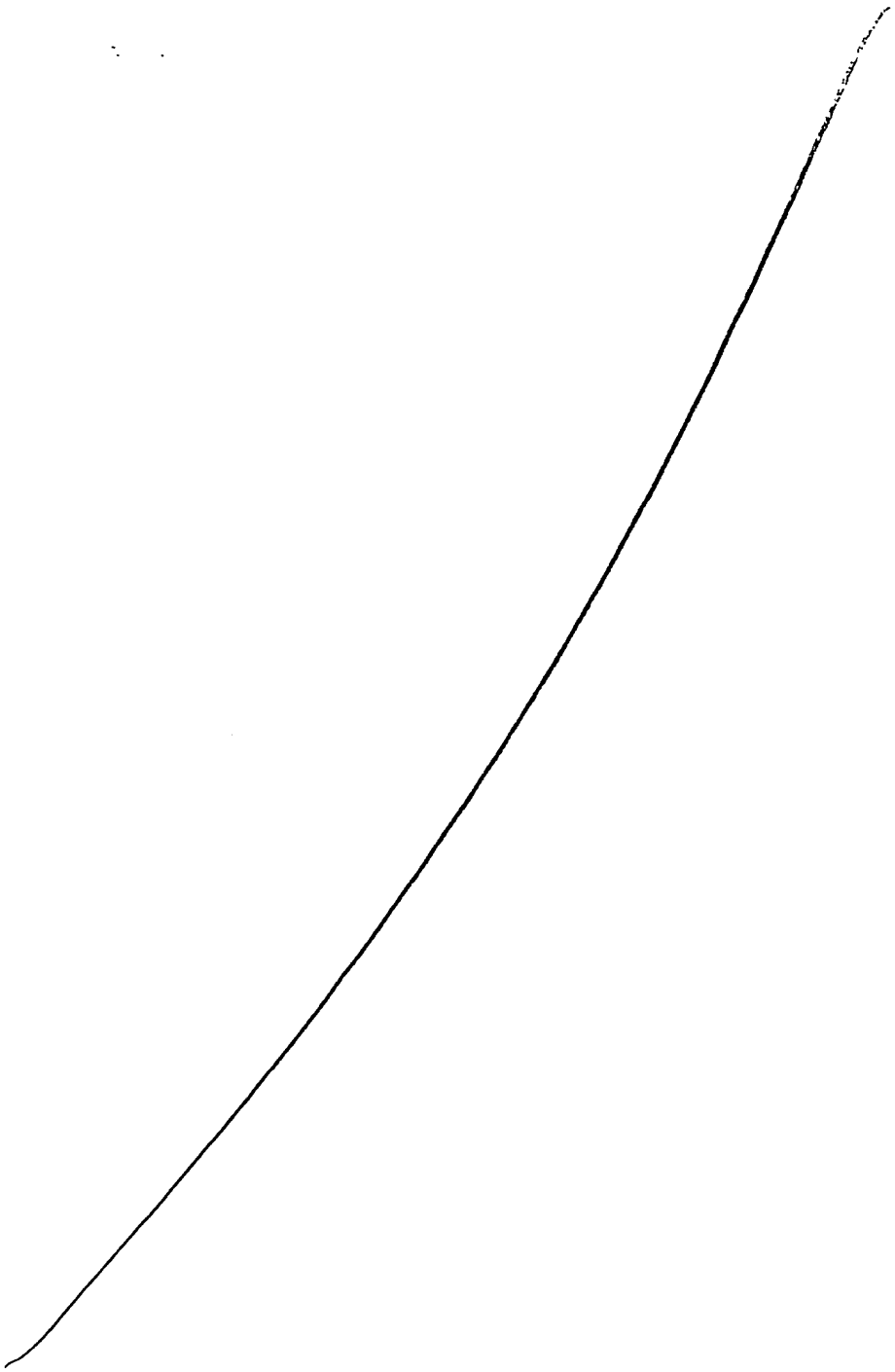

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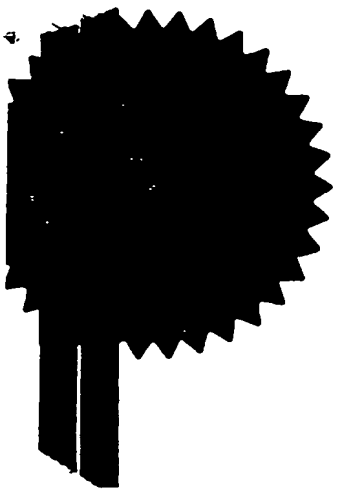

Signed A W Brewer

Dated 6 MAR 2000

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The Patent Office

Cardiff Road
Newport
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1. Your reference — DM/EN/P08788GB

2. Patent application number *(The Patent Office will fill in this part)* — **9902253.5**

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Rotech Holdings Limited,
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Mastrick Industrial Estate,
ABERDEEN, AB2 6HQ,
Scotland, United Kingdom.

Patents ADP number *(if you know it)*

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4. Title of the invention — IMPROVEMENTS IN AND RELATING TO BEARINGS

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Cruikshank & Fairweather,

19 Royal Exchange Square,
GLASGOW, G1 3AE,
Scotland, United Kingdom.

Patents ADP number *(if you know it)* — 547002

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body
See note (d))

YES

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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
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Request for substantive examination *(Patents Form 10/77)*	
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Signature CRUIKSHANK & FAIRWEATHER Date 02/02/99

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Dr. David Moreland
0141 221 5767

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Thrust bearing assemblies for use in down-hole applications have the conflicting requirements of a thick shaft assembly and high axial load bearing capacity in a small cross-section. To achieve this a number of thrust bearings may be mounted in line to provide sufficient load and shock capacity. In conventional bearing assemblies this introduces a problem as the load may not be shared equally between the series of bearings which may result in excessive wear or failure of one or more of the bearings. This problem can be mitigated by use of assemblies of springs and spacers. However, these tend to be complex in nature. An additional problem in down-hole apparatus is that space tends to be limited.

It is an object of at least one aspect of the present invention to obviate or mitigate the aforementioned problems in the prior art.

It is a further object of at least one aspect of the present invention to seek to provide a flexible, load sharing, anti-friction bearing assembly/unit.

According to a first aspect of the present invention there is provided a bearing assembly having at least two bearing elements spaced by a first body, the first body

having means for flexing.

Thus when a load is applied to the bearing assembly the first body may be caused to flex.

Advantageously the flexing means may comprise at least one groove or notch formed on the first body.

Preferably the first body is substantially annular in shape, the at least one groove preferably being formed on an outer surface of the first body.

Advantageously the groove is substantially U-shaped.

The first body may be rigidly mounted to a body to which load is applied, in use.

Preferably a first annular surface of the first body is provided with a first annular raceway.

Preferably also, a second annular surface of the first body is provided with a second annular raceway.

Advantageously the first and second bearing elements each comprise a plurality of balls, the first and second bearing elements preferably being received for movement within the first and second annular raceways of the first body.

According to a second aspect of the present invention there is provided a bearing unit comprising at least one and preferably a plurality of bearing assemblies according to the first aspect.

Advantageously each adjacent bearing assembly are spaced by a second body.

Preferably the second body is substantially annular in shape.

The second body may be rigidly mounted to a further

body to which load is not (directly) applied in use.

Preferably a first annular surface of the second body is provided with a first annular raceway.

Preferably also, a second annular surface of the second body is provided with a second annular raceway.

Advantageously, respective first and second bearing elements may be received for movement within the first and second annular raceways of the second body.

Advantageously, adjacent first bodies are spaced by a respective first spacer element.

Advantageously also, adjacent second bodies are spaced by a respective second spacer element.

According to a third aspect of the present invention there is provided a tool or apparatus including a bearing assembly according to the first aspect of the present invention or a bearing unit according to the second aspect of the present invention.

The tool may be a down-hole tool, e.g. for use in a borehole of an oil/gas well.

The tool may comprise part of a borehole drilling apparatus, which may include a down-hole motor such as a Moineau motor of a motor as disclosed in WO 95/19488, the content of which is incorporated herein by reference.

The first body may be rigidly mounted to a shaft to which load is applied, in use.

The shaft may be contained substantially concentrically within the bearing assembly/unit.

The second body may be rigidly mounted to a housing.

The housing may substantially concentrically surround

the bearing assembly/unit.

Advantageously, adjacent first bodies are longitudinally spaced by a first spacer element, which may also be mounted on the shaft.

Advantageously also, adjacent second bodies are longitudinally spaced by a second spacer element, which may also be mounted on the housing.

An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, which are:

Fig. 1 a portion of a down-hole tool including a bearing assembly according to an embodiment of the present invention;

Fig. 2 a perspective view of a portion of the bearing assembly of Fig. 1.

Referring initially to Fig. 1 there is illustrated a portion of the down-hole tool, generally designated 5, according to an embodiment of the present invention. The tool 5 may take the form of a borehole drilling apparatus. The tool 5 includes a bearing unit (pack) 10 comprising a series of adjacent bearing assemblies 15 - in this embodiment three assemblies 15 are provided.

Each bearing assembly 15 has two anti-friction bearing elements 400 spaced by a first body 500, the first body 500 having means for flexing. Thus, when a load is applied to the bearing assembly 15, the first body 500 is caused to flex. In this embodiment the flexing means comprise at least one groove 510 formed on the first body 500.

The first body 500 is substantially annular in shape,

the at least one groove 510 being formed on an outer surface of the first spacer body 500. As can be seen from Figs. 1 and 2 the groove 510 is substantially U-shaped.

The first body 500 is rigidly mounted to a shaft 600 to which load is applied, in use, the shaft 600 being substantially concentrically contained within the bearing unit 10. The shaft 600 may be hollow and may have a socket 610 for connection, e.g. to a drill bit or the like (not shown).

A first annular surface 610 of the first body 500 is provided with a first raceway 620. Further a second annular surface 630 of the first body 500 is provided with a second annular raceway 640. The first and second bearing elements 400 each comprise a plurality of balls, the first and second bearing elements 400 being received for movement within the first and second annular raceways 620, 640 of the first body 500.

The bearing unit 10 comprises a plurality of bearing assemblies 15. Each adjacent bearing assembly 15 are spaced by a second body 200. Each second body 200 is substantially annular in shape. The second bodies 200 are rigidly mounted to an outer housing 100 to which load is not (directly) applied, in use.

A first annular surface 650 of each second body 200 is provided with a first annular raceway 660. A second annular surface 670 of each second bodies 200 provided between adjacent assemblies 15 is provided with a second annular raceway 680. Second bodies 200 provided at ends of the unit 10 are only provided with one raceway 660.

In this way respective first and second receiving elements 400 are received for movement within the first and second annular raceways 660, 670 of the second spacer body 200.

Referring to Fig. 1 the second bodies 200 are rigidly mounted to a housing 100. The housing 100 substantially concentrically surrounds the bearing unit 10.

A first raceway 620 of the first spacer body 500 faces a second raceway 680 of a second body 200. Similarly a second raceway 640 of the first body 500 faces a first raceway 650 of a second body 200.

As can be seen from Fig. 1 the first bodies 500 are longitudinally spaced along the shaft 600 and separated by first spacer elements 700 which may be rigidly mounted to the shaft 600. Further as can be seen from Fig. 1 the second bodies 200 are longitudinally spaced along the housing 100 and separated by second spacer elements 300 which may be rigidly mounted to the housing 100.

It is noted that the shaft 600 is free to rotate relative to the housing 100. Thus the first bodies 500 may rotate relative to the second bodies 200.

The components of the tool 5 may, in this embodiment be made from the following materials:

housing 100	-	steel
second bodies 200	-	hardened steel
second spacer elements 300	-	steel
bearing elements 400	-	hardened steel and/or ceramic
first spacer bodies 500	-	hardened steel

shaft 600	-	steel
first spacer elements 700	-	steel

In use, the flexibility of each bearing assembly 15 provides load sharing throughout the bearing unit 10. This flexibility is imparted by the grooves 510. As a (thrust) load F is applied to the shaft 600 a first body 500 deflects or flexes under the load F seeking to ensure that the next first bodies 500 are suitably positioned such that some of the load is then transferred through the adjacent inner spacer 700 to the next first body 500 and so on. This seeks to ensure that the load F is spread evenly between the bearing assemblies 15 in the unit 10, and is not supported by a single bearing assembly 15. Thus the load F is distributed in a way which is not possible using known rigid bearing assemblies. As each body 200, 500 is double sided the load F may be either tensile or compressive. In either case the load F will be shared over each of the bearing assemblies 15 of the unit 10.

It will be appreciated that the embodiment of the present invention hereinbefore described is given by way of example only, and is not meant to limit the scope of the invention in any way. It will, for example, be understood that the number of bearing assemblies forming a bearing unit may be selected to provide a desired load capacity.

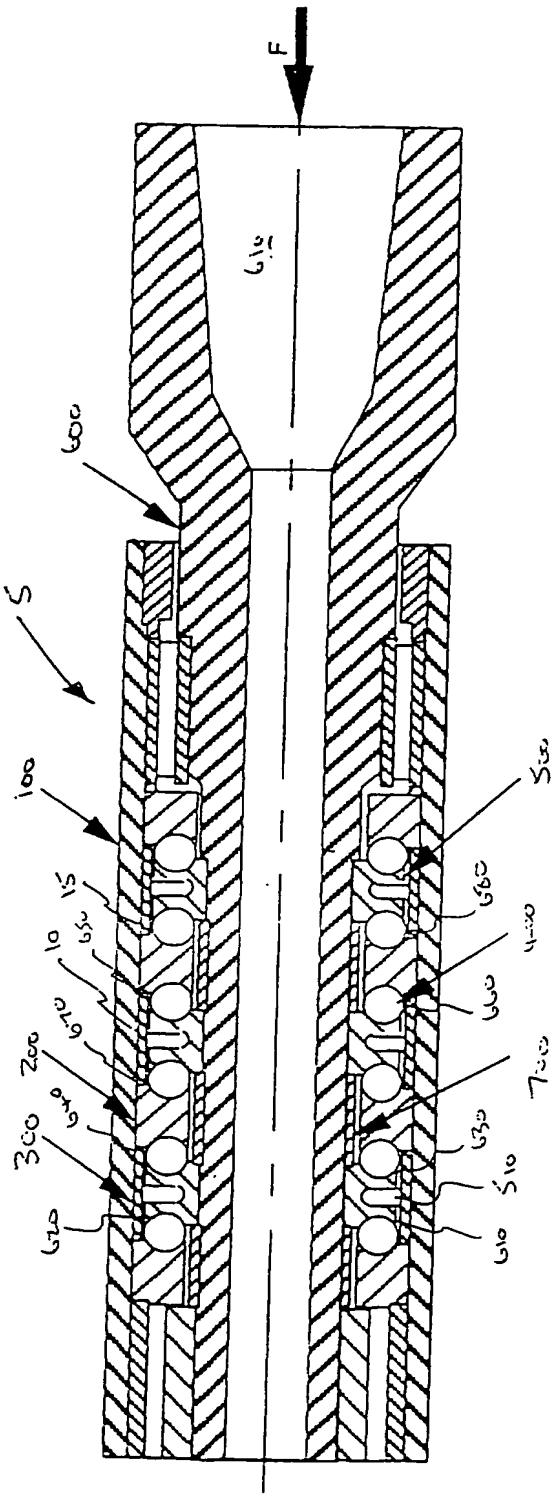
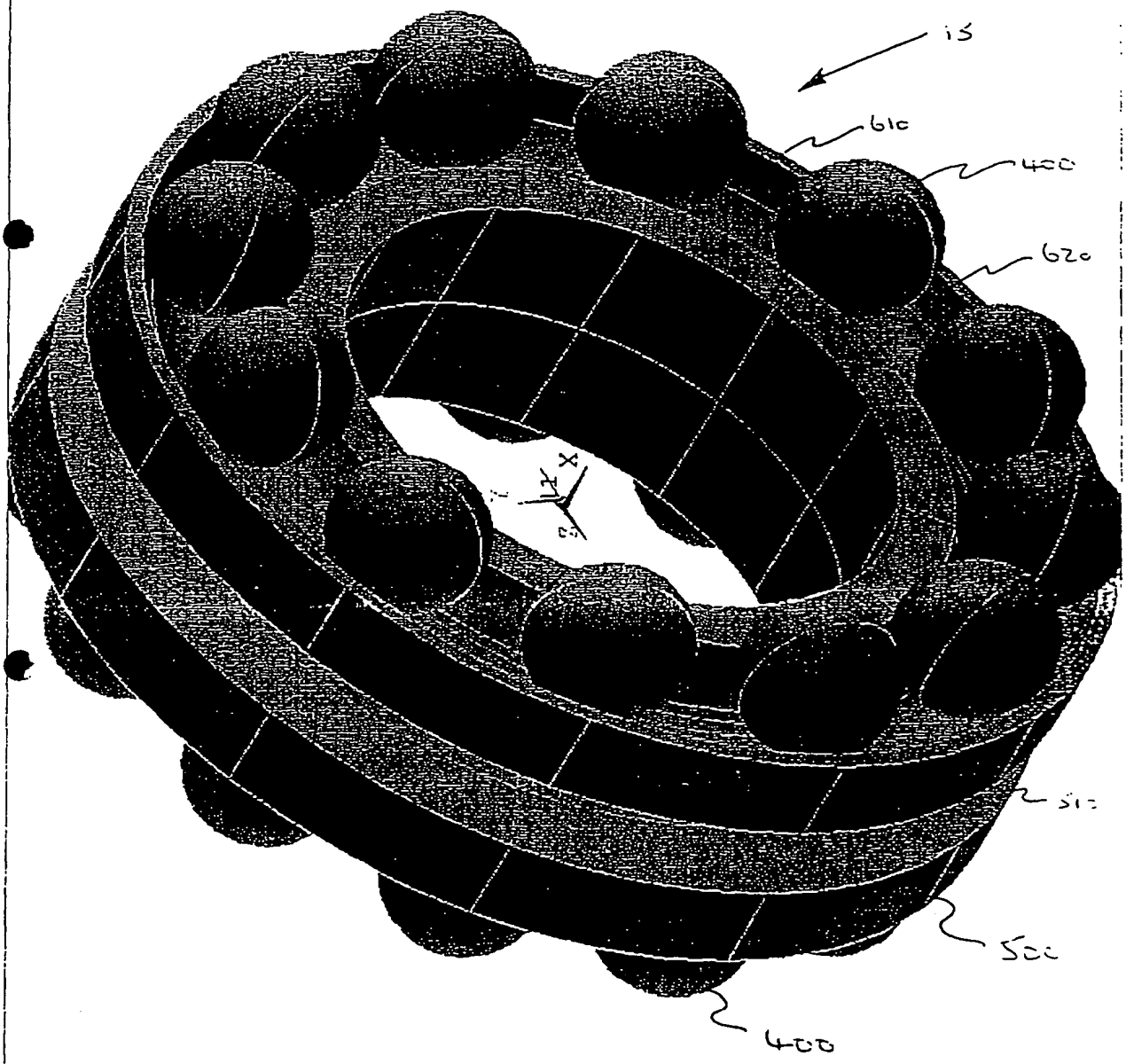


Figure 1

FIG. 2



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Cruickshank + Fairweather.

31/2/06